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Design Manual:

Removal of Arsenic from Drinking Water by Ion Exchange

by

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Foreword

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Hugh W. McKinnon, Director
National Risk Management Research Laboratory

Abstract

This design manual is an in-depth presentation of the steps required to design and operate a water treatment plant for removing arsenic in the As(V) form from drinking water using the anion exchange process. Because As(III) occurs as an uncharged anion in ground water in the pH range of 6.5 to 8, the process will not remove As(III) unless it is first oxidized to As(V). The manual also discusses the capital and operating costs, including many of the variables that can raise or lower costs for identical treatment systems.

The anion exchange treatment process is very reliable, simple, and cost-effective. The treatment process removes arsenic using a strong base anion exchange resin in either the chloride or hydroxide form, with chloride the preferred form because salt can be used as the regenerant. The process preferentially removes sulfate over arsenic; and, therefore, as the sulfate increases in the raw water, the process becomes less efficient and more costly. Furthermore, because sulfate occurs in significantly higher concentrations than arsenic, treatment run lengths are dependent almost entirely on the sulfate concentration of the raw water. The ion exchange process is a proven efficient and cost-effective treatment method for removing As(V) from water supplies with low sulfate levels.

The configuration of an anion exchange system for As(V) removal can take several forms. The method presented in this design manual uses three vertical cylindrical pressure vessels operating in a downflow mode. Two of the three treatment vessels are piped in parallel to form the primary arsenic removal stage. The third treatment vessel is piped in series in the lag position. In the primary stage, raw water flows through one of the two treatment vessels while the second vessel is held in the standby position. When the treatment capacity of the first vessel approaches exhaustion, it is removed from service and replaced by the second primary stage vessel. While out of service, the first vessel is regenerated and placed in the standby position. The role of the third treatment vessel in the lag position is to ensure that any arsenic that breaks (peaking) through one of the lead vessels does not enter the distribution system. Although this design concept results in higher capital costs, it prevents high arsenic concentrations in the treated water, if operated properly.

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Abbreviations and Acronyms

ANSI	American National Standards Institute
APHA	American Public Health Association
ASME	American Society of Mechanical Engineers
AWWA	American Water Works Association
BAT	best available technology
BV	bed volume(s)
CPVC	chlorinated polyvinyl chloride
EBCT	empty bed contact time
EPDM	ethylene propylene diene monomer
ETV	Environmental Technology Verification
FRP	fiberglass reinforced polyester
GFAA	graphite furnace atomic absorption
GHAA	gaseous hydroxide atomic absorption
gpd	gallons per day
gpm	gallons per minute
ICP-MS	inductively coupled plasma–mass spectrometry
MCL	maximum contaminant level
N/A	not applicable
NPT	National Pipe Thread
NSF	NSF International
O&M	operations and maintenance
OSHA	Occupational Safety and Health Administration
PL	Public Law
PLC	programmable logic controller
psi	pounds per square inch
psig	pounds per square inch gage
PVC	polyvinyl chloride
SBA	strong base anion
SDWA	Safe Drinking Water Act (of 1974)
STP	stabilized temperature platform
TCLP	Toxicity Characteristic Leaching Procedure
TDS	total dissolved solids
U.S. EPA	United States Environmental Protection Agency
WEF	Water Environment Federation

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